ANNUAL REPORT OF THE FLORIDA BAY SCIENCE OVERSIGHT PANEL:

Perspectives from the 1996 Florida Bay Science Conference and Review of the Strategic Plan

Submitted to the

Program Management Committee
Interagency Florida Bay Science Program

by

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Florida Bay Science Oversight Panel

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INTRODUCTION

The Florida Bay Science Oversight Panel (FBSOP) is an independent peer-review group, charged with providing regular, broad, technical, and management review of the Interagency Florida Bay Science Program. It reviews agency plans; Program Management Committee (PMC) strategies for program development; scientific quality of research, modeling and monitoring; and research results (Armentano et al., 1994; 1996). The Panel consists of seven senior scientists with significant experience in major estuarine restoration programs but without involvement in Florida Bay projects. The FBSOP submits an Annual Report which assesses progress and directions in the Program based on its participation in the annual Florida Bay Science Conference. The first Annual Report was produced in November 1995 (Boesch et al., 1995); this is the second Annual Report.

The second annual Florida Bay Science Conference was held on December 10-12, 1996, in Key Largo, Florida. There were 35 oral presentations made at the Conference, most of which summarized results from several related projects. These were organized around five central questions identified in the Strategic Plan for the Program (Armentano et al., 1996). A member of the PMC introduced each Central Question and the groups of presentations were followed by questions from the FBSOP and audience and general discussion among the presenters. The oral presentations are cited here by the name of the first author and page number in the Program and Abstracts (Anonymous, 1996). Nearly 60 posters were also displayed during one session. Poster presentations are cited by the name of the lead author and poster number (e.g. P21).

Following a recommendation made in 1995, at PMC request the Panel arranged for *ad hoc* committees of experts in specialized subjects to participate in three workshops where critical science issues were addressed during 1996. For continuity, members of the FBSOP participated in each of these committees. Reports from the committees were submitted to the PMC on each of the workshops:

- circulation modeling, April 17-18, 1996 (Armstrong et al., 1996);
- nutrients, July 1-2, 1996 (Boesch et al., 1996); and
- water quality modeling, October 22-24, 1996 (D'Elia et al., 1996).

The PMC also requested the FBSOP to review the D*raft Strategic Plan for the Interagency Florida Bay Science Program* sent to the Panel just prior to the December Conference. This review was informally transmitted to the PMC in early January, 1997, and is included as a section of this Annual Report.

General Observations and Recommendations

1. **Workshops.** The workshops held during 1996 were very successful from the perspective of the FBSOB. The involvement of external reviewers in these workshops has produced effective advice and the participation of FBSOB members has allowed continuity in the oversight efforts. It is important to keep in mind, however, that these workshops should primarily be a mechanism for investigator communication, consensus building, collaboration, and planning. In the future, it is recommended that appropriate FBSOB be involved in the planning of the workshops with as much lead time as possible in order to schedule attendance and assemble a knowledgeable and independent *ad hoc* review committee for the workshop.
2. **FBOSP Accountability**. It is recommended that the PMC prepare on an annual basis and in advance of the Annual Science Conference a “score card” which reports what has been accomplished pursuant to recommendations of the FBOSP and the *ad hoc* review committees or provides other appropriate responses (e.g., “we disagree,” “we tried that and it didn’t work,” “not in our purview,” etc.). This would provide: (a) feed back to the FBOSP in order to avoid reinventing the wheel and help focus subsequent, implementable recommendations; (b) impetus for moving the program forward; and (c) demonstrate responsiveness and program quality to outside world.
3. **Scientific Program Manager/Chief Scientist**. The FBSOP is very pleased to hear of the PMC’s plan, as stated in the Strategic Plan, to create a full-time science program manager position devoted to providing leadership in program integration. Placing the right person in such a position and giving him/her appropriate responsibility and resources will make a big difference. In addition to the alternative of assignment of an agency scientist to this task, the PMC should consider engaging an experienced and highly regarded environmental scientist via a Interagency Personnel Agreement for a fixed term (e.g. 2 years).
4. **Program Integration**. It is clear that the PMC is making considerable efforts to effect needed integration of results and understanding. Progress toward this end is clearly being made. Of course, much more needs to be done. The FBSOP offers the following recommendations for advancing program integration:
   - Use the water quality model development to provide impetus for integration in terms of providing necessary inputs and evaluating sensitive assumptions.
   - Continue the use of large workshops and effective use of facilitators, but tie research team tasks with the workshops, either in preparation of syntheses to be aired at the workshop or post-workshop meetings to pull together the existing information.
   - Set timetables which challenge the research teams to meet integration goals.
   - Continue to improve consistency of spatial reference and station coordination to improve synergy and efficiency.
   - Standardize key methods which provide routine or shared data, e.g. chlorophyll.

- Devote a small amount of funds to support short term research or analyses which might provide new insights which advance broader understanding of the ecosystem (see 1995 recommendations).

PERSPECTIVES FROM THE 1996 FLORIDA BAY SCIENCE CONFERENCE

Below the Panel provides evaluation and recommendations regarding investigations which address each of the five central questions identified by the PMC. Some of the questions (e.g. Central Question #1) are treated in greater detail than others (e.g. Central Question # 5). This is a reflection of a number of factors, particularly the stage of development and integration of studies which address each question, rather than any level of importance assigned to the questions.

CENTRAL QUESTION #1

How and at what rates do storms, changing freshwater flows, sea level rise and local evaporation/precipitation influence circulation and salinity patterns within Florida Bay and the outflow from the Bay to adjacent waters?

Hydrology, Circulation and Modeling

Circulation modeling has been a high priority since the first external review of the evidence concerning the deterioration in the Florida Bay ecosystem and the relationship between this deterioration and freshwater inputs (Boesch, et al. 1993). Based on that initial review and subsequent conferences and workshops, it has been learned that Florida Bay circulation is complex, a function of tidal and wind forcing and sea level slopes across the Bay's ocean boundaries, and that both large-scale flow and local bathymetry influence water movements. Mean flows are from the northwest to the southeast with considerable exchange both along the western boundary and through inlets between the Keys. Residence times within the northeastern Bay are considerably longer than in the central or western Bay, and this difference may have been exacerbated both by the construction of the Flagler Railroad in about 1910 and, subsequently, the Overseas Highway and by sediment accumulation resulting from an absence of hurricanes over the last few decades. Freshwater inputs include surface and groundwater from the adjacent peninsula as well as intense seasonal and episodic rainfall events directly on the Bay surface. Mean salinity and seasonal hypersalinity may have increased within the Bay as a result of water management practices, although historical variations in salinity are large, and restoration of the South Florida Ecosystem, of which Florida Bay is a part, is certain to include hydrological manipulations that can cause changes in Bay circulation and water quality.

One of those recommendations of the 1993 assessment panel was to expand the knowledge of water flow, both within the watershed, within the Bay, and between the watershed and Bay and to "develop and verify a two-dimensional hydrodynamic/water quality model of the Bay into which boundary currents, tides, surface and groundwater flows, precipitation, evaporation, and winds are incorporated to create a tool capable of predicting circulation, residence time, salinity and water quality under different flow and climatic conditions."

The Florida Bay Science Plan (Armentano et al., 1994) embodied this recommendation for a circulation model by including as one of its tasks the development of "a circulation dynamics model for Florida Bay". The model was to "incorporate existing model structure from other water bodies as much as possible" as well as "be capable of simulating circulation and transport across the Bay as a whole, both within the major sub-environments and within local basins". It was expected that ecological modeling efforts would proceed in parallel and cooperatively with the circulation model. Further, it was believed that a two-dimensional circulation model would suffice unless it was shown later that a three-dimensional model would be needed. Finally, integration of the circulation model of Florida Bay with larger-scale physical oceanographic, hydrological, and meteorological models that would provide boundary conditions and forcing functions was desired, as was inclusion of erosion and sea-level rise as two continuing processes.

The subsequent draft Strategic Plan for the Interagency Florida Bay Science Program (Armentano et al., 1996) identified the relative importance and dynamic interactions of the relevant physical processes affecting Bay circulation as an important need. Relatively precise quantitative predictions of how the physical and, subsequently, the dependent chemical conditions of the Bay will change as restoration proceeds and flows are altered are needed. The effects of natural forcing phenomena (e.g., exchanges with surrounding waters, hurricanes and sea level rise) also must be known. Knowledge of these details is critical if Bay circulation is to be related to water quality and biota within the Bay and transport to the coral reef tracts in the Florida Keys National Marine Sanctuary.

To answer these questions, a series of studies has been implemented or planned by the PMC (Armentano et al., 1996) dealing with modeling, empirical studies, monitoring, and historical data analysis. One eventual product would be an operational, fully verified physical model to underpin water-quality and ecosystem models supported by continuing data acquisition (monitoring) and with uncertainties in model output carefully delimited.

Development of the circulation model has proceeded over the past two years following a purposeful strategy. During the 1995 Florida Bay Science Conference, several mathematical models of circulation in Florida Bay were presented and discussed. Finite-segment, two-dimensional, and three-dimensional models had been developed and/or applied to the Bay as part of a strategy to examine several modeling approaches. Based on the work presented at that conference, the FBSOP recommended that a three-dimensional modeling approach should be selected and further developed. One of the models presented at that conference was a two-dimensional model developed by the U.S. Army Corps of Engineers and being applied to Florida Bay by Lisa Roig and others at the Corps of Engineers' Waterways Experiment Station (Boesch et al., 1995; Anonymous, 1996).

It is the Corps model which has become the primary circulation model effort for Florida Bay, and it, along with associated models, was the subject of review by an ad hoc committee at the Florida Bay Modeling Workshop held in Marathon, Florida in April, 1996 (Armstrong et al., 1996). The objective was to evaluate current activities to ensure the best possible outcome in circulation model development for Florida Bay with emphasis on compatibility, linkages, and suitability for related activities including additional modeling, research, and restoration. That committee was charged to evaluate circulation models for their appropriateness for Florida Bay; to look for missing opportunities and holes in activities within the program; to identify future needs; and to focus on timeliness, technical transferability, date requirements, and relevance to current issues.

That Panel came to the following conclusions:

1. The two-dimensional RMA2 finite element model may be an appropriate choice by WES to simulate Florida Bay circulation given the Jacksonville District's narrow initial emphasis of using the model to determine the impact on Florida Bay salinity of modifications to the C-111 canal; however, the Panel does have concerns regarding linkage of RMA2 with a sediment transport model and ultimately with a water quality model.
2. While an unstructured finite element network may be an appropriate choice to represent the narrow cuts and highly variable resistance to flow within the Bay, the number of elements currently in the RMA2 model probably can be reduced lowering the model's run time while retaining the desired resolution. Also, the bathymetry used with this grid must be the most recent available. The network needs to be extended westward and northward along the west coast of Florida to accommodate expanded boundary conditions.
3. The boundary conditions are inadequately addressed at this time. Freshwater inflow from surface water and groundwater emanating from the Everglades into the Bay must be characterized. The western boundary should be extended over the shelf and northward of the Shark River inflow point and boundary conditions offshore of the Keys must be determined.
4. Water quality modeling, including seagrasses and benthic exchange, is an essential tool in the development of the restoration plan for Florida Bay and that such modeling be initiated as soon as practicable.
5. The following are needed: a central repository and vigorous coordination of field measurement programs, additional hydrodynamic field measurements on the western boundary of the Bay, and additional water quality data to support a water quality modeling effort.
6. Groups for coordination of field data collection, hydrodynamic model evaluation, and water quality model selection should be formed to support the data collection and modeling efforts in and around Florida Bay.

A workshop on the design and specifications of the Florida Bay Water Quality Model was held in October, 1996, in Key Largo "to focus on the identification of model components and activities critical to the management of Florida Bay". The evaluation committee assembled to observe the workshop proceedings constitutes a Model Evaluation Group (MEG), which will review and advise the model development effort. The MEG made recommendations about future directions of this modeling effort. Several of these were directly related to circulation modeling as follows:

1. Practical management alternatives and issues must motivate the [water quality] modeling effort; the model must be able to: provide managers with the necessary information to determine optimal freshwater flows and diversions; determine any

physical alternations necessary to manage water flow; and predict water quality changes to the extent possible.

2. The water-quality model must be able to address the following issues: source, fate, and distribution of nutrients; trend and fate of seagrass populations as affected by nutrients, turbidity, and salinity; resuspension of sediments and impacts of light penetration; distribution and occurrence of planktonic algae blooms; and distribution of salinity, brackish water, and hypersalinity.

3. Development and implementation of a hydrodynamic model to link with the water quality model is a high priority, and the COE/WES CH3D model is recommended because it has been linked to water quality and sediment quality models elsewhere. Specific recommendations pertinent to circulation modeling were:

    - preliminary implementation of CH3D should begin before the RMA2 unstructured, finite-element circulation model is finished;
    - the CH3D model should be used in 2D or 3D-mode to simulate larger scale circulation between basins to insure that hydrodynamic and water quality model linkage is practical;
    - the calibrated RMA2 model should be used to explore questions about fine-scale circulation patterns occurring over mud banks, between basins, through the Keys, and at the western boundary, because difficulties will arise in implementing CH3D in such a shallow, irregular estuary;
    - projecting salinity distributions and freshwater impacts from the alteration of C-111 canal and other freshwater flows will likely require a coarser grid than the one currently under development;
    - reproducing measured salinity distributions at various scales is a critical task, thus, a fine scale RMA2 simulation should be calibrated to existing salinity distribution data and a subsequent simulation used to provide a more comprehensive data set for calibrating a coarser scale CH3D circulation pattern at critical times; and
    - expectations and goals should be explicitly agreed to by key players at the outset and be kept realistic by avoiding the inclusion of too many elements in the model, starting simply and adding complexity only as necessary, and using auxiliary research models to address a few specific management issues.

It is appropriate that the conclusions of the Boesch et al. (1993 and 1995) panels, the Armstrong et al. (1996) recommendations and the Corps' response to them (Holland et al. 1996), and the D'Elia et al. (1996) recommendations be addressed as comments and conclusions are drawn about the presentations made relative to the circulation model at the 1996 Florida Bay Science Conference. This is appropriate because the circulation and water-quality modeling work being done in the Florida Bay Science Program most certainly falls on the "critical path" of the task (project) flow chart. Not only will examination of restoration alternatives depend on the availability of a coupled, calibrated, and confirmed circulation/water-quality model, but consideration of many hypotheses about the temporal and spatial relations of phytoplankton, sea grasses, and other biota to circulation and water quality will benefit by its availability also. Because of this critical importance of the modeling effort, it is vital that progress on the circulation and water quality models be timely and substantial but also that those projects which will provide information to those models (e.g., bathymetry, boundary water levels and fluxes) also show timely and significant progress. This urgency was in the mind of the Panel as it reviewed the work being performed, both that reported orally or in poster format and that work in progress but not reported.

At this 1996 Florida Bay Science Conference, progress made in several of these projects was reported, and comments on the progress being made are given below:

Florida Bay Circulation Model (COE/WES): Lisa Roig (70) reported on the salinity and hydrodynamics modeling commissioned by the Jacksonville District COE to investigate the effects of the C-111 canal freshwater releases on the circulation and salinity distributions in Florida Bay. The project has responded to earlier workshop recommendations (Armstrong et al. 1996) about extending the western boundary but not to the practical need to reduce the excessive number of finite elements (Armstrong et al., 1996; D'Elia et al., 1996). Holland et al. (1996) have responded to the comments made in Armstrong et al. (1996) regarding the RMA2 model and indirectly to similar comments made in D'Elia et al. (1996), and, while there may be scientific disagreement about the circumstances under which grid coarsening may occur and whether one approaches hydrodynamic modeling with simple-to-complex or complex-to-simple approaches, the net result is that WES is undertaking several actions so as to provide a hydrodynamic model for Florida Bay. According to Holland et al. (1996), WES is planning to complete development of the fine-grid RMA2 model for Florida Bay using its considerable computational facilities, to develop in parallel a coarse-grid version of RMA2, though [questionably] "with a resolution below which the fundamental character of circulation within the Bay is lost", to consider CH3D (a structured, coarse-grid hydrodynamic model) which is linked to CEQUAL-ICM (the water quality model being modified for Florida Bay), and to link directly RMA2 with CEQUAL-ICM. That linkage would possibly obviate the need to use CH3D if RMA2 can be made to run efficiently on workstation-class computers. Except for the expansion of the finite-element grid westward and the fall data collection of water fluxes through several of the inlets of the Keys, development of the RMA2 model and collection of field data for calibration does not seem to have made much progress since the April workshop. Roig (70) noted the data needed for the model, particularly data needed from others (e.g., bathymetric and friction data from USGS), but she provided essentially no information on progress in calibrating the model to simulate tides, water levels, or currents. There was also no information provided on interfacing the RMA2 model with boundary condition models, although again Holland et al. (1996) note that tidal boundary conditions are being obtained from the WES model, ADCIRC, for the Caribbean and Atlantic Oceans and from the NOAA-Princeton model for coastal Florida.

Given the lack of information provided about progress and the plan to have the model completed in early 1997, there appears to be a substantial amount of work to do in a very short period of time. It appears that it will be difficult to bring the RMA2 model to the point that it will be able to address the limited requirements of the COE to address salinity distribution changes from freshwater management of the C-111 canal, much less serve as the hydrodynamic driver for the proposed water quality model. A more detailed report from WES specifically on hydrodynamic modeling progress is needed, and perhaps this could be provided with the work plans WES is providing for the water quality modeling effort.

It is important to keep the processes of model development open to the contributions of regional experts, including both those studying water quality, geochemistry, and ecology and those employing other modeling approaches. Sheng (P43) has been more successful in simulating Florida Bay circulation that the COE/WES model at this point. He has made excellent progress in expanding his hydrodynamic model to simulate wetting and drying. Since this code is the original code from which the COE CH3D model derived, this bodes well for the water quality modeling effort. Clearly, Sheng has much to contribute and should be given ready and equal access to all data sets and be invited to contribute to planning and assessment meetings.

Regional Circulation Model (NOAA): There was no report on this important investigation in which the Princeton Ocean Model is being applied to the oceanic waters adjacent to the Bay to provide oceanographic boundary conditions and forcing to the Bay circulation model. The COE/WES memorandum by Holland et al. (1996) did note that: "WES has ongoing cooperation with NOAA in South Florida [and that] data exchange has already occurred," so it is assumed that progress is being made in this project. It is critical that this project have useful results available to the circulation modelers in a timely fashion, and that those results include measures of uncertainty for water levels, velocities, and fluxes. Given the known sensitivity of Florida Bay circulation to sea level slopes across its breadth, uncertainty in these results must be available to gauge their usefulness to the project.

Regional Atmospheric Model (Mattocks, NOAA): Mattocks' (55) report indicates that progress is being made not only in defining regional climatic patterns which affect rainfall patterns in the area but also in examining the impacts of urbanization and of putting more water in the Everglades on those rainfall patterns. Willis et al.'s (100) investigations of rainfall and evaporation and Powell and Houston's (P46) investigations of wind fields should also provide important inputs for physical modeling of Florida Bay. Such efforts should be utilized rather than duplicated by the COE model. However, it seems likely that circulation and water quality modeling will not simulate hurricane events, yet these remain important events for the ecology of Florida Bay that must be analyzed and projected. Perhaps a parallel effort to predict the effects of hurricanes can be undertaken which links physical observations and models, sedimentologic and paleoecological studies, and evidence from 20th Century hurricanes, e.g. the 1935 hurricane and Hurricane Donna.

Rainfall Estimation Improvement (NOAA, SFWMD): Willis et al. (100) reported good progress in developing the NEXRAD data into estimates of precipitation. The research steps being followed are largely those used in similar applications of the method in mid-latitude subtropical regions; the major difference in the two applications is the raindrop size distribution, and the purpose of the project is to refine the radar-rain algorithms as needed to make rainfall estimates more accurate. Calibration of the modified algorithms with ground truth data is also being performed.

Physical Oceanography Data Collection (NOAA): A data sets that is proving to be of immense value for understanding circulation patters in the western portions of Florida Bay and the boundary waters is that of Lee et al. (48). Through the use of drifters, moored current meters, and a vessel equipped with a continuous flow thermosalinograph-fluorometer and a broad band acoustic Doppler current profiler, movement of the Shark River plume has become characterized to some extent, net transport through Channels 2, 5, and Long Key Channel have been estimated, and cross-shelf flow in the Long Key region has been described. This information will be quite useful to those developing the circulation and water quality models, and the work should continue to understand in some detail circulation in this part of the Bay. Mattocks (55)is developing interesting simulations of the sea breeze and development of convective storms in south Florida. He is making standard boundary layer calculations of evaporation that extends to Florida Bay. This effort should be coordinated with the salinity-hydrodynamics model of Florida Bay that also requires reasonable estimates of evaporation to simulate hypersalinity in the central basin.

Bathymetric Data Collection (USGS): Prager et al. (68) noted in their abstract that the bathymetric data collection program began in the summer of 1995 and is anticipated to be completed in 1998. This new information will be quite valuable to the hydrodynamic modeling effort, and it is presumed that communication of this information is taking place between the USGS and the COE/WES as it becomes available.

Measuring And Simulating Freshwater Inflows (USGS, NPS): The work of Swain and Patino (81) began initially as an attempt to measure the flow of freshwater from the Everglades into Florida Bay through Buttonwood Ridge, and, based on the poster presentation by Patino (P34), good progress has been made in establishing monitoring stations, measuring water levels and velocities, and developing relationships between water level and flow. Once the latter relationships are established with confidence, then water-level measurements taken over the past year may be converted to flow, and the first good estimates of freshwater flow directly to the Bay from the Everglades should be available. These measurements will continue into the future providing daily estimates of flow. Plans were presented to apply a two-dimensional model (the USGS model SWIFT2D) with a regular grid (1000 ft x 1000 ft) over the area along the C-111 canal and down to Florida Bay. The model is limited to surface water only, although it may be coupled with a groundwater model, but such coupling is not being done as part of this work. Questions were raised about implementation of the model, how boundary conditions were to be established, particularly along the western border, and other points.

Following the presentations, the Panel came to several conclusions regarding the technical aspects of the modeling program which are given below.

1. Given the interdependent nature of the hydrodynamic and water quality modeling programs, it is appropriate that they be combined as a study unit within the Florida

Bay Project and that reviewers who evaluated the circulation and water quality modeling at separate 1996 workshops be coalesced into one Model Evaluation Group.

2. Because the hydrodynamic and water quality modeling will most certainly fall on the critical path of the Florida Bay Project, it would be appropriate for the PMC to prepare a schedule for completion of the hydrodynamic and water quality models so that the COE/WES knows the time-frame in which it is operating and those engaged in other activities providing critical input to the modeling activity may be appropriately scheduled also.

3. It is not clear based on the information presented at the Conference what progress is being made with the RMA2 model to simulate water levels and tidal variations, and, given the present schedule for this model's completion, it is not clear that it will, in fact, be developed for Florida Bay to the point that it will actually provide circulation information. The COE/WES is in the process of deciding whether to use (a) the RMA2 as is with coupling (which is being developed) to CEQUAL-ICM, (b) the RMA2 with grid coarsening, or (c) the CH3D model (in two-dimensional form). They will have to develop a decision process (with criteria) by which to decide which model to use. The Panel believes it is important that this decision process, the criteria, and the timing of the decisions be included in the work plan the COE/WES is preparing for the water-quality modeling effort.

4. Because there were no presentations on progress being made using the NOAA regional circulation model and the COE/WES ADCIRC model to provide boundary conditions on the western, southern, and eastern boundaries of the Bay, it is not clear where that work stands. The PMC should determine the status of this work and ensure it is interfaced with the hydrodynamic modeling activity on a continuing basis.

5. Studies on the regional atmospheric model and rainfall estimation improvement appear to be making good progress.

6. The physical oceanography data collection work also appears to be making good progress. There does need to be coordination and cooperation to the extent possible between investigators and agencies to avoid duplication of effort and to maximize resources. A step to this end is the development of the single map showing sampling stations of all data collection efforts as recommended by Armstrong et al. (1996); this rather simple step still has not been taken by the PMC. Another desirable step is the development of a database system; an *ad hoc* one is forming on the Internet apparently at the initiative of the various principal investigators, but the PMC should determine whether a more centralized one would benefit all investigators.

7. The PMC needs to insure that bathymetric data communication is taking place between USGS and the COE/WES so that current bathymetric information is being used in the RMA2 model grid.

8. While good progress is being made to characterize flows in the streams through the Buttonwood Ridge, the PMC should examine carefully the freshwater inflow modeling portion of this work to determine the likelihood that this work will provide useful results eventually.

Geology and Paleoecology

Geologic studies (both stratigraphic and paleoecologic) are providing a valuable insight into the evolution of Florida Bay, both from a relatively short-term time perspective (human time frame) and from a longer-term perspective (Holocene sea level rise over the past 5000 years). Such studies serve as a basic line for evaluating whether contemporary sedimentologic and geochemical changes are induced by human activities or merely record recurring natural phenomena.

In general, there is considerable evidence of interaction and cooperation within the sedimentologic and paleoecologic working groups based on presentations at the 1996 Conference. This interdisciplinary cooperative effort is illustrated by the Whitewater Bay Project (Nelson et al., 62) which is integrating sedimentology pollen studies, microfauna and stable isotopes, and geochronology and trace metal geochemistry to evaluate the potential of the sediment record as monitor of natural and anthropogenic changes in the Lower Everglades/Florida Bay ecosystem. Similarly, Florida Bay mudbank stratigraphic and paleoecologic studies are being integrated through research efforts by Brewster-Wingard et al. (25).

From a realistic viewpoint, it appears likely that these sedimentologic and paleoecologic research projects are in a mature state and results should be summarized and synthesized in the relatively near future (1-2 years). Beyond these studies, new approaches other than the traditional analyses relating abundance and diversity of molluscs, foraminfera, ostracodes to historical salinities should be attempted to establish whether the recent crisis in Florida Bay is simply another episode in a naturally occurring cycle or is it unique to contemporary conditions. These may involve chemical, sedimentological or biological indicators reflecting seagrass abundance and algal blooms. For example, Frewin (1994) published an abstract of a study specific organic markers, including ones for seagrass cell walls, in 22 cores from Florida Bay. Such a taphonomic approach might merit a revisit. Similarly, retrospective analysis of iron and iron precipitates in cores might provide insight into salinity fluctuations as well as phosphorus geochemistry. Clearly, determination of whether such phenomena as massive seagrass die-offs, chronic turbidity and algal blooms that we now attribute to ecosystem dysfunction, in fact, periodically occurred prior to human influence is central to defining management options.

Baseline studies of bathymetry and overall sediment budget are necessary to better understand the parameters needed to model the circulation in Florida Bay and to provide a framework for remediation or restoration of components of the Florida Bay ecosystem. Such studies presently underway by the USGS are essential. Repeated references throughout the presentations to resuspension of sediments with accompanying increases in turbidity and reduction of light levels, suggest that this sedimentologic aspect should be considered in greater detail. Praeger et al. (68) briefly reported on a series of USGS projects, including work on sediment resuspension, carbonate geochemistry, and the bathymetry of Florida Bay. Considerable progress has been made on the sediment resuspension element during the past year, including the collection of extensive data on bottom types and seagrasses at over 600 sites. The highly focused studies of the effects on frictional response are critical to the development of resuspension estimates as well as to hydrodynamic model calibration. The bathymetric surveys should also be quite important for hydrodynamic modeling and other purposes. Further, the proposed “shaker device” to determine the shear stress necessary to resuspend Florida Bay sediments from core samples should lead to the development of resuspension coefficients

Swart and Healy (82) have expanded their isotopic studies of coral annulations as paleosalinity indicators to include another smaller, but more widely distributed, coral as well as mollusks to provide a more extensive coverage of Florida Bay. These new studies strengthen the earlier conclusions that the construction of the Flagler Railroad in the Florida Keys created a major shift in Florida Bay salinity towards more evaporative conditions. In addition, the 1989 peak in salinity is clearly evident in the smaller coral (*Siderastrea*) collected from the northern portion of Florida Bay.

CENTRAL QUESTION #2

What is the relative importance of the influx of external nutrients and of internal nutrient cycling in determining the nutrient budget of Florida Bay? What mechanisms control the sources and sinks of the Bay’s nutrients?

Detailed presentations and discussions on the question of the sources of nutrients and the relationships of nutrients to seagrass die-off and algal blooms were made during the July 1996 workshop. External review comments and recommendations were made by Boesch et al. (1996). Although some new information was presented at the December Science Conference, the conclusions and recommendations presented in that evaluation remain largely appropriate. The following comments supplement the previous review.

Nutrient Budgets

Extensive data on nutrient concentrations and sources have now been collected but comprehensive interpretation of these data is sorely lacking. While the water-quality model will conduct a rigorous mass balance, the it will not address the pressing issues for a year or more. In addition, the water-quality modeling efforts require organization of the source data and investigation of gaps in the data. Clearly, Bay and basin-wide nutrient balances are needed, as was courageously attempted for organic carbon by Swart et al., (84) but at a much more detailed level. Nutrient balances are vital to addressing the causes of persistent algal blooms, the management of wastes in the Florida Keys, and assessments of C-111, Taylor Slough, and Shark River impacts. The next step is to quantify fluxes and cycling of nutrients. The planned water-quality model must eventually address these balances, but the Panel reiterates the recommendations from the workshop on Florida Bay nutrients (Boesch et al., 1996) that preliminary box models of nutrient budgets are needed at this stage.

Groundwater Sources

What seems to be receiving less attention, but may well turn out to be of major significance, is the role of groundwater in the Florida Bay system, not only the relatively localized tidal pumping adjacent to the Florida Keys (as demonstrated by Shinn et al., 74), but also possible subsurface seepage through the shallower aquifer or the deeper Miocene artesian system along the northern margin of Florida Bay (as suggested by Larry Brand in his presentation at the Conference).

None of the presentations presented data that characterize the complex permeability characteristics found in South Florida carbonates. Although saltwater intrusion is generally recognized in the shallow surface along the northern margin of Florida Bay, deeper groundwater systems have not been considered. Such systems may have high conductivity, as demonstrated by Shinn et al. (74) along the Florida Keys, or may isolate local freshwater reservoirs through vertical permeability barriers. Assuming a groundwater reservoir model characterized by both vertical and lateral homogeneity may lead to erroneous modeling and restoration attempts. Additional drilling and geochemical monitoring of test wells are needed to determine whether or not the contribution of subsurface seepage plays a major role in the overall composition of Florida Bay waters.

Shinn et al.'s (74) findings are consistent with the effects of astronomic and wind tides on flow in porous media. However, conclusions drawn are entirely too speculative about potential overall effects. A simple Darcy's law calculation of the potential flux should be performed without delay. These water-flux calculations can be contrasted with inlet-flux measurements by the COE and others. Meanwhile, the isotope measurements by Böhlke et al. (P54) provide strong evidence that nutrient wastes from the Florida Keys are not a significant source of nutrients to the Atlantic reef tracts.

The "show stopping" development of the 1996 Conference was Brand's suggestion that an important, unrecognized source of nutrients to Florida Bay is the so-called "river of sand," a buried river channel that may be a conduit of phosphorus from mining and farming areas north. To appropriately target research to such a critical issue, the PMC should support a group of investigators to resolve key questions concerning conductance, residence time, nutrient concentrations, recharge areas and surface effluent zones.

Other Sources

Rudnick et al. (72) and Sklar et al. (P51) reviewed interesting nutrient flux measurements along several transects or paths of freshwater flow from Taylor Slough into Florida Bay. These studies seem to be at an early stage, but are likely to provide valuable flux measurements of a Florida Bay mass balance of nutrients, which are urgently needed. These data also should be valuable to validate edge calculations by the Everglades Landscape Model from the SFWMD, that in turn is valuable to simulating the nutrient mass balance in Florida Bay. The data should also be valuable to developing an ecosystem model of the mangrove fringe-Buttonwood Ridge area, and perhaps of Florida Bay. However, the tie into the overall program and the Florida Bay water quality model needs to be more clearly defined. At the moment, the potential impact of the work cannot be clearly assessed.

Dillon (P33) claimed that nutrients emanating from the Florida Keys nutrients must also be considered in the Florida Bay nutrient mass balance. Although his tracer studies show that nutrients from septic tanks do move into the Bay they do not demonstrate that such fluxes are quantitatively significant other than on local scales immediately adjacent to the Keys.

Atmospheric deposition remains an unquantified, but potentially significant source of nitrogen for Florida Bay, either via direct deposition on the Bay surface or deposition on the lower Everglades.

Nutrient Geochemistry and Cycling

Florida Bay provides a unique opportunity for a modern comprehensive study of phosphorus-carbonate geochemistry. Clearly there is a need to know this for modeling efforts and for understanding nutrient availability to primary producers. In the past, P-carbonate relationships have been viewed too simplistically. In fact, some of the original and frequently cited research indicates that P adsorption to carbonates exhibits complex kinetics, and is a function of carbonate minerals but also sediment surface characteristics and organic matter in the sediments.

There were several conclusions that the long-term nutrient history of Florida Bay had not changed in decades; this remains a viable research hypothesis. Any conclusion of “no change” should be made with a caveat about the power of the analysis (power in the literal or figurative statistical sense, i.e. probability of acceptance of a null hypothesis of no effect when one exists). Although the $\delta^{13}C$ data of Swart et al. (82) seem to correlate with storms that could flush organic matter out of the Bay, the relative lability of the organic matter needs to be calibrated. This will also be important for assessing the effects of the defoliation and death of mangroves following Hurricane Andrew and the contribution of increased seagrass detritus to initiating the plankton blooms. Currently, sufficient data might exist to calculate whether the blooms could have been initiated by the seagrass die-off and how long this detritus could help sustain the blooms.

The effects of sediment destablilization after loss of seagrasses on releasing nutrients to water column and its role in sustaining phytoplankton blooms is undetermined, although very preliminary data suggest that the effect might be minor. Carlson et al. (29) found little P was released after mixing sediments in sea water. P was not fluxed to the water column from sediments formerly vegetated by seagrasses and N flux was higher in the presence of seagrasses. Fourqurean and Frankovich (37) found that seagrass C:N:P ratios have not changed substantially post-die-off, although the size of effect necessary to conclude there was a change was not addressed (i.e., the power of analysis). Seagrass root/rhizome physiology and, possibly, porewater salinity fluctuations impose non-steady state conditions on sediment diagenesis that virtually negates use of diagenetic models to determine the role of the sediments in nutrient cycles in the Bay. Instead, attention should be focused on empirical measurements of diagenetic rates. It would also be useful to explicitly state the hypotheses for the effects of pH, salinity, organic matter (mass and source), etc. on sediment nutrient processes important to Florida Bay dynamics.

Communication of these hypotheses to investigators not involved in nutrient process work might foster complimentary data gathering when possible.

Water Quality Model

Dortch (32) adequately summarized the consensus of the October 1996 workshop on the design and specifications for the Florida Bay water quality model as documented in the Model Evaluation Workgroup report (D'Elia et al. 1996). This workshop was a successful meeting of selected scientists who reviewed what is known about important resources, and water quality modeling experts. The Florida Bay investigators presented what is known about seagrass, nutrients, plankton, benthic algae and epiphytes, sediment resuspension, and other water quality processes. The modelers reviewed the state-of-the-art in simulating nutrients, suspended sediments, salinity, light extinction, seagrasses, phytoplankton, and carbonate chemistry. The workshop reached a workable consensus on a practical management model for water quality that Dortch reported on in detail. The model proposal will define generic model requirements, benchmarked to the CE-QUAL-ECM model by the COE. Based on the report the COE will solicit one or more proposals and these proposals will be peer-reviewed. It is vital to the team building process that this process of selecting a water quality model and experts to calibrate and interpret the model, be open to better proposals. This open process will also aid in achieving better cooperation with data collection groups. Please refer to additional comments concerning the water-quality model development under Central Question #1.

While the Panel encourages the development of the water quality model both as a management tool and a means to direct research to answer key questions about the Florida Bay ecosystem, we also must raise caution concerning false expectations and over-reliance on models. Just the creation of a water quality model will not magically lead to ready development of a restoration strategy for Florida Bay. Models are approximations and will always have errors in simulating nature. They do not always give good predictions of the outcomes of management schemes. Rather, the water quality model should be just a part of the scientific assessment and it is appropriate at this stage to define the realistic expectations from ecosystem/water quality models and how they will be used to foster development of a restoration strategy.

CENTRAL QUESTION #3

What regulates the onset, persistence and fate of planktonic algal blooms in Florida Bay?

The following observations are offered regarding the scientific activities that address this question:

1. The research community has made considerable progress in the past two years to characterize algal blooms in Florida Bay. Notable advances include:
    - An emerging picture that Florida Bay can be partitioned into regional zones that have their own character and functional dynamics. For example, analyses of Boyer

and Jones (19) identified a freshwater-dominated Eastern Bay, a Western Bay influenced by shelf waters, and the Core Bay as an evaporative basin. This regionalization of the Florida Bay system is an important step toward understanding the considerable spatial variability of algal communities and blooms. In addition, aerial maps of water color (FDEP) show the monthly-scale changes of bloom distributions within these different zones.

- Measured rates of primary productivity, and inferred demands of N and P by the phytoplankton communities in the different regions of Florida Bay (Tomas, 89). This is essential information (that hopefully will be published soon), confirming that Florida Bay is extremely heterogeneous and highly productive in some zones.
- Measured rates of microalgal ingestion by zooplankton, and identification of microzooplankton grazing as a large sink for phytoplankton biomass (Dagg and Ortner, 30;Vargo et al., 97).
- Preliminary experiments suggesting that the benthic filter-feeding community might also be an important sink for phytoplankton biomass, with further suggestions that spatial or temporal fluctuations in the benthic grazer community could be an important control on bloom dynamics (Vargo et at., 97). Limited new experimentation suggests that tunicates, sponges, and some mollusks can ingest the very small cells of *Synechococcus*, thus the cyanobacterial blooms are potentially influenced by grazing pressure. This population of small-sized cells might be a food resource for suspension-feeding invertebrates.
- Fundamental taxonomic information to define the species composition of algal blooms within the different regions of Florida Bay, including the identification of indicator species suggestive of nutrient enrichment in the northern zone (Steidinger and Phlips, 77).
- Laboratory experimentation on algal isolates to define the growth kinetics and light-salinity-nutrient-temperature responses of some bloom species (Richardson, P19).
- A developing sense of how the water quality of Florida Bay changes in response to annual fluctuations in precipitation and freshwater inflow, e.g. the trend analyses of Boyer and Jones (19).
- Exploitation of satellite imagery to hindcast trends of changing turbidity (Stumpf and Fayer, 80). This analysis is especially important because direct measures of turbidity are not available for the past decade of rapid change in Florida Bay. The lack of coherence between fluctuations in satellite-derived turbidity and measured chlorophyll strongly suggests that blooms are not events of resuspended benthic chlorophyll.
- New information showing large concentrations of chlorophyll within the sediments (although we are uncertain about the spatial distribution, temporal fluctuations, and contribution to system productivity of the benthic microalgae).

2. The progress noted above is useful for characterizing patterns of phytoplankton population variability. The next phase of research from these investigators should move toward synthesis/integration of these results to define the underlying mechanisms of bloom variability within Florida Bay. One approach should be construction of seasonal population budgets for the discrete zones of Florida Bay to define the changing balances between phytoplankton population growth (including relative importance of nutrient and light limitation), grazing losses, sedimentation, and horizontal transports. This analysis would ideally be done as a team exercise in which principal investigators work together to produce the conceptual model and population budgets to explain the initiation, persistence, and fate of microalgal blooms in Florida Bay. The 'algal dynamics research team' should also begin active collaboration with other research teams of the Florida Bay Science Program. In particular, investigators of algal dynamics should work closely with teams studying paleoecology (to explore similarities and differences in the contemporary and historical communities of phytoplankton), circulation (to understand the role of transport patterns in the development and dissipation of blooms), and pelagic and benthic grazer communities (to understand the role of top-down processes)..

3. In spite of the advances noted above, there remains considerable uncertainty about the recent biotic 'shifts' in Florida Bay and whether these represent changes induced (or amplified) by anthropogenic nutrient inputs, or whether these changes are phases of natural alternations between dominance by planktonic and benthic plant communities. Unfortunately, an appropriate record of observation and measurement is not available to document the sequence and spatial extent of the changing nutrient inputs and plant communities within Florida Bay. This critical information gap creates a situation in which consensus within the scientific community will be difficult to achieve on the critical questions of the magnitude and impacts of nutrient enrichment. At this point, the only recourse for resolving the issue appears to be exploitation of the sedimentary record to search for signals that could be used to reconstruct the history of the trophic status of Florida Bay. We strongly encourage the paleoecology team to explore all approaches that might give meaningful information about the changing trophic condition of Florida Bay, including the organic components (pigments, biomarkers, etc.) and biotic communities (including indicator species) of the sediment record.

4. The Panel is fully supportive of the PMC effort to resolve the discrepancy between chlorophyll measurements made by different laboratories working in Florida Bay. Chlorophyll concentration is a primary descriptor of the status of microalgal blooms, and the PMC should expect close agreement (i.e., differences less than ten percent) between measurements made by different laboratories. Chlorophyll determinations of the monitoring program are especially critical because diverse teams of the Florida Bay Science Program will use this record to: derive estimates of productivity and nutrient uptake; describe the seasonal cycles, trends, and spatial patterns of blooms; partition seston among organic and inorganic components; and calibrate the water-quality and biogeochemical models expected to guide restoration of Florida Bay. Although we have not participated directly in the inter-laboratory comparison of chlorophyll determinations, we understand that deviations of results among laboratories are large,

determinations from the monitoring program are often lower (sometimes by a factor of 2, 3, or even 5) than those from other laboratories, and samples from the monitoring program are collected by pressure filtration in a syringe. This procedure is not standard (standard methods use low-vacuum filtration at less than 0.5 atm), and we believe that chlorophyll determinations from the monitoring program might be underestimates if algal cells are lysed by this high-pressure filtration. Even more disturbing is the possibility that the error might not be systematic if the degree of lysis varies with the compositional makeup of the phytoplankton community. We suggest that the PMC organize a more systematic assessment of the accuracy of chlorophyll determinations made within the monitoring program, including determinations of the loss of chlorophyll by syringe filtration. This assessment should address the reliability of historic measurements, and should include specific recommendations about future methodology for inclusion in the monitoring program. We view this as an issue that requires immediate attention.

CENTRAL QUESTION # 4

What are the causes and mechanisms for the observed changes in the seagrass community of Florida Bay? What is the effect of changing salinity, light, and nutrient regimes on these communities?

Much progress has been made toward focusing on critical aspects of the problem of declining seagrass communities. First, it is clear that land-derived nutrients did not have an appreciable role in initiating seagrass die-off, except possibly near the Keys. Second, there is also consensus that salinity plays an important role in controlling seagrass biomass and distribution within Florida Bay. The role of disease in causing seagrass die-off also is appreciated as important.

A tangible difference in the discussions of this year was that the quality of the existing database for support of the various alternative hypothesis for seagrass die-off was evaluated more rigorously. This has lead to more openness and objectivity in considering what is known about seagrass biology, as opposed to what is strong belief, albeit based on long experience. The value of recognizing that existing data on salinity and temperature effects on seagrasses are inadequate for evaluating causes of die-off or recovery potential should lead to the development of research directed to a functional understanding of how these parameters after seagrass response variables. This progress will be critical for the modeling efforts.

The *Labyrinthula* research program is well-coordinated with field scientists, is very directed to questions, and includes an ecological perspective. Although *Labyrinthula* has not been demonstrated to kill *Thalassia*, it is more pathogenic at higher salinity. The following points are recognized and there is a plan to be address them in the future. It will be necessary to determine the rate of transmission in the field. Because the *Labyrinthula* spp. associated with wasting diseases of other seagrasses is known to attack primarily stressed seagrasses, it is critical to determine whether the pathogen can initiate a die-off without concomitant physiological stress. Identification of other important pathogens hopefully will be pursued. Finally, pathogens suspected of causing the initial die-off must be able to reproduce the symptoms observed during the initial die-off (seagrass meristem weakness, detachment of whole shoots), which are not necessarily ones primarily associated with *Labyrinthula* infection.

Progress in providing research products, e.g., maps of seagrass distribution and cover and light transmittance, has been made and should continue. Particularly useful would be a GIS base for algal bloom and sediment plume distribution, light transmittance, temperature, salinity, and seagrass distribution.

Although data on epiphyte and macroalgal loads in Florida Bay seagrass beds are available, there are no data on their potential grazers. Juvenile pinfishes are present seasonally (according to Mike Robblee) but scarids and other macroherbivores (sea urchins) are not abundant. There is no information on mesoherbivores such as amphipods, isopods, and snails that can control seagrass epiphytes at least to some level of eutrophication in other systems. Epiphyte biomass is used as a indicator of eutrophication problems in seagrass beds but it cannot be concluded definitively that the absence of increased epiphyte growth indicates that eutrophication was/is not a problem without accounting for loss of epiphytes to grazers. Unfortunately, due to this data gap in Florida Bay, it will be impossible to hindcast the role of mesograzers in preventing epiphyte overgrowth in response to chronic but small increments in nutrient loading in the Bay before the seagrass die-off. Nevertheless, seagrasses apparently did not die off from epiphyte overloads. Although there is no reason to devote top priority to epiphyte grazers presently, understanding grazing intensity on epiphytes might be useful in determining the capacity for seagrasses to recovery and should not be overlooked.

Rhizophytic green algae are early colonizers of seagrass beds and can stabilize sediments although not to the degree that seagrasses can. They recruit and grow fast and tolerate lower irradiance compared to seagrasses. The DEP includes these algae in their benthic vegetation surveys; this data set will be useful in determining the ecological process of seagrass recovery, if possible.

Sediment microalgae have a high potential for primary productivity and intercepting benthic nutrient fluxes. They also have some capacity for transient sediment stabilization and can fix large masses of nitrogen despite close proximity to typically high sediment ammonium concentrations, and their productivity has apparently increased following seagrass decline (Brandt and Hitchcock, 22). Zimba (1995) measured ^{14}C uptake rates by sediments that were almost as high as seagrass carbon uptake at 2 sites in the Bay (one pristine, one die-off). Although these organisms are sometimes overlooked in ecosystem studies, they are not in Florida Bay studies.

Attention was directed to the *Syringodium* beds at the western boundary of Florida Bay, where there is concern for the status. These beds might provide an opportunity to test some of the predictions made from the research effort.

Little discussion was made concerning the recovery potential of the seagrasses within the Bay, beyond controlling *Labyrinthula* if merited upon further research. Although the researchers clearly recognized that light was a very important factor to seagrass distribution and recovery, only minimal discussion and effort was evident at the meeting. Seagrass transplantation into unvegetated, declining, and other areas would serve as a research tool as well as acting as living indicators of water quality and sediment stabilization. This approach has been invaluable in evaluating the dynamics and recovery of submersed vegetation in the Chesapeake Bay.

The PMC posed the management question of the effects of manipulation of freshwater flows into Florida Bay on seagrass communities and its importance to restoration efforts. Light will undoubtedly interact with salinity and temperature effects and experimenters should strive for fully-crossed designs.

The modeling exercises and research to identify the causality of seagrass decline and the potential for recovery clearly need to be based on sound physiological ecology. Mesocosms, combined with field manipulations with transplantation, will become critical for research progress. Currently, apparently there are only two seagrass mesocosm facilities. Facilities with temperature and salinity controls must be available and care should be taken that they are filled with carbonate sediments appropriate for Florida Bay. Researchers are aware that mesocosm seagrass is susceptible to high incidence of disease; mesocosms might fortuitously provide complementary pathogen studies. Mesocosm work is difficult, and in some past seagrass research there has been substantial doubt about interpretation and quality of data due to mesocosm artifacts. Good communication about mesocosm problems should occur among local and other scientists. To this end, it might be useful to initiate site visits to mesocosm facilities by scientists familiar with the problems and seagrasses, for the purpose of providing advice.

The die-off is a natural experiment that offers unique research opportunities for seagrass biologists and other benthic ecologists. Some attention could be given to how this experiment could be exploited, beyond the critical concern for re-establishing an important natural resource. Today, there are unanswered questions about the 1920's wasting disease of eelgrass that should be revisited in order to avoid wishful thinking 50 years from now. Questions concerning trophic structure and benthic-pelagic coupling are obvious; others might not be, for example, the potential for rapid microevolution of seagrasses through changing allele frequencies during what might be a genetic bottleneck.

Now that the initial response to the seagrass die-off crisis is over, it was clear from the results of the final discussion group at the end of the seagrass session that seagrass biologists have broadened their perspective from the inital die-off crisis to a broader ecosystem one in which seagrasses represent “foundation” communities. Seagrass beds are critical ecosystem components that have some of the broadest functions within the Florida Bay ecosystem: from dissipation of physical energy to being engines of primary production and nutrient cycling to trophodynamics and other support for living resources. If a system-wide ecological model is considered valuable, seagrass beds offer a manageable unit. The seagrass biologists working in Florida Bay represent probably the highest concentration of experienced seagrass biologists in the U.S. They should provide a thread of ecological continuity throughout the various questions and components of the Florida Bay research and restoration plans.

CRITICAL QUESTION #5

What is the relationship between environmental and habitat change and the recruitment, growth and survivorship of animals in Florida Bay?

The Panel's general impression is that the work on the effects of changing conditions in Florida Bay on higher trophic levels has not progressed much from the 1995 review. It is essential that a conceptual model of higher trophic levels in Florida Bay be developed. This model could be developed via a workshop; however, an essential component of that workshop is the inclusion of three to five outside scientist who would bring different perspectives. One or two of those outside scientists need to be 'big picture' systems thinkers and one or two need to be modelers who can help formulate the linkages between the hydrodynamic, geochemical and biological variability of Florida Bay. This workshop can be used to 1) synthesize existing information, 2) identify key processes, and then 3) develop a strategic plan for integrating these processes into a numerical model.

Hypersaline or extreme temperature conditions are not well integrated into the thinking of what controls higher trophic level abundance. Changes in some components of the fish community, such as the increase in bay anchovy, may be a simple response to changing salinity, not increased zooplankton abundance. Both salinity and temperature are thought to be major controlling factors in fish habitat selection and growth and survivorship.

Information on higher trophic level distribution and production needs to be scaled to the whole system, not described site by site. An obvious approach, recommended in the Boesch et al. (1995), would be to link changes in the fish and shellfish community with changes in seagrass habitat. It is possible that on the whole-system level the loss of the seagrass habitat, while dramatic in a local site, had a negligible effect on the total community. Another approach would be to use the outputs from the hydrodynamic and water quality model (salinity, temperature and seagrass habitat) to predict areas of high and low fish and shellfish production based on physiological and habitat requirements of individual species. These predictions could then be tested against actual measurements of growth or production.

Links to hydrodynamic flow need to be considered, particularly with regard to recruitment. Recruitment and spread of many fishes and swimming invertebrates throughout the Bay from localized spawning sites is often controlled by hydrodynamics governed by freshwater discharge, tidal circulation and wind forcing. Much of the management proposed is focused on altering hydrology, yet little consideration has been given to the impacts of altered hydrology on the transport of fish and shellfish larvae.

More emphasis needs to be placed on understanding changing plant and animal composition on ecosystem processes and trophic pathways. For example, shifts in forage fish from surface to bottom can have important effects on wading birds, while loss of sponges leads to decreased filter feeding and perhaps increased algal blooms. These kinds of feedbacks are not being considered.

More work needs to be done on the processes of growth, recruitment and mortality; and less on documentation of standing stock. We will never be able to make predictions unless we can understand what controls the processes that determine production. The Panel suggests that focused field experiments including process measurements coupled with modeling should be the next step in the evolution of research on higher trophic levels.

REVIEW OF THE STRATEGIC PLAN

The PMC requested a rapid review of the draft Strategic Plan (Armentano et al., 1996) provided for the Panel just prior to the December Science Conference. Although the Panel had little time to review the Strategic Plan in advance and had to concentrate on the extensive information presented at the Conference while in Key Largo, we were able to discuss the Plan in general terms and assembled this overview, with limited comments on its specific program elements. However, the Panel's preceding comments on the progress and direction of the Science Program as evidenced by the presentations made at the Conference offer considerable advice relevant to future Program Elements under the five central questions.

GENERAL COMMENTS ON THE STRATEGIC PLAN

The Oversight Panel believes that the Strategic Plan:

1. Advances Program Focus, Direction and Integration.

The Panel commends the PMC for taking the time to produce a thoughtful Strategic Plan for the Science Program required to guide restoration of Florida Bay. This document gives clear definitions of the mission and role of the PMC and the relationships between the PMC and Restoration Managers and the Oversight Panel. It also states restoration objectives. The present Strategic Plan is a major advance from the 1994 Interagency Science Plan and represents the growing maturity of the Science Program.

Most importantly, the Strategic Plan greatly improves the focus of the Science Program from the overly diffuse 1994 Plan. The five Central Questions on which the Plan is now focused have relevance to restoration objectives and management needs and should also serve effectively to direct, organize and prioritize research, monitoring and modeling activities. Other elements of the Strategic Plan that are particularly commendable are:

- recognition that the five Central Questions are difficult and require multiple approaches, including the integration of monitoring, experimentation, and modeling;
- the logical approach to each Central Question that begins with an inventory of what is currently known (indicating judicious consideration of a vast amount of often conflicting information), lists remaining key unknowns, and finally outlines general and specific approach for addressing the critical gaps in understanding;
- the greater emphasis on causality and mechanisms of ecosystem changes, relative to descriptive surveys and monitoring;
- the multiple scales and modes of communication and synthesis, including the use of workshops to bring together researchers working on a broad range of related issues (e.g., nutrients, circulation, seagrasses), and Research Teams to work toward syntheses of data to answer focused questions;

- the identification of the need to create a full-time program manager position devoted to providing leadership in program integration; and
- the evolving components of outreach to explain the goals, approaches, and progress of the Florida Bay Science Program to the public, officials, and students.

These are positive attributes that together define a strategy for acquiring the fundamental understanding of the Florida Bay ecosystem required for the establishment, and then implementation, of a restoration strategy. Toward that end, it is important that the PMC maintains a self-critical and innovative approach to implementation. The strategy should not just be a packaging of existing agency programs. Also, it should “push the envelope” in the application of potentially profitable approaches not presently being employed by the Florida Bay science community. A notable example is use of modern experimental techniques for studying algal blooms.

As in any strategy, many decisions remain to be made within the context of the Strategic Plan. The five Central Questions are very broad. Priorities regarding specific studies will undoubtedly have to be set both between and within the Central Questions. As progress is made the questions and identified needs will evolve. While all five questions are important, the Panel points out that Central Questions three and four are at the heart of restoring Florida Bay to a healthy condition. We need to understand the causes of seagrass mortality and algal blooms and their relationships to management options much better.

2. Responds to the Recommendations of External Reviewers.

The Panel is particularly pleased that the PMC has been quick to act on many of the previous recommendations of the Oversight Panel and the *ad hoc* teams of reviewers that have participated in the 1996 workshops and is proposing to act on others under this Strategic Plan. The focus on a smaller number of questions, increased emphasis on causality and mechanisms, convening of problem-oriented workshops, implementation of electronic communication networks, attempt to formulate restoration goals, standardization of geographic terminology, formation of research teams, and plan to appoint a full-time science program manager are consistent with and responsive to the recommendations of external reviewers. From our perspective, the participation of Panel members and other external experts in the 1996 workshops was particularly effective in providing more detailed advice than we are able to provide on an annual basis and we urge that this approach be continued.

3. Is Appropriately Directed toward Restoration Goals.

Admittedly, the restoration goals for Florida Bay are difficult to define at this point, but more specific goals must be identified in order to define and evaluate progress. The research teams and researchers must have a clear understanding that their research should be directed to setting restoration goals. Currently this understanding is not always apparent; research is directed to answering questions about the “natural“ former state of the Bay and to determining reasons for declining ecosystem function. While this is helpful in determining the conditions necessary for returning the ecosystem to some former state, the Science Program should evolve toward defining the restoration goal and evaluating the management options to reach this goal as explicit objectives.

Throughout the Strategic Plan it is emphasized intentionally or otherwise that restoration of natural salinity variations is a goal. Although the plan states that this would be pursued if supported by research and modeling, it might be important to emphasize more strongly that this is only one hypothetical example of a restoration goal, perhaps by suggesting alternative goals based on current knowledge. The concern is to avoid having salinity regimes being accepted prematurely as the problem (or sole problem), particularly with the seagrass decline. Such overemphasis could serve to limit useful explorations of other restoration scenarios. Similarly, the Panel believes the hypothesized mechanisms leading to long-term changes in Florida Bay presented in Figure 2 are useful for developing hypothesis-driven research and modeling, but cautions against inferences that the explanations embodied in this model have been confidently demonstrated. The presentations of "what is known" seem to us occasionally slanted to certain tenets which are not yet supported by compelling evidence. For example, we are uncomfortable with vague references to multiple stresses as a cause of seagrass mortality. The relative importance and interactions of these stresses is yet to be determined.

Adaptive environmental management, which has been widely emphasized in recent reports on ecosystem management (Interagency Ecosystem Management Task Force, 1995; Christensen et al., 1996; Keystone Center, 1996)and seems particularly appropriate given the present uncertainties regarding the Florida Bay ecosystem, suggests that alternative explanations be embraced (Walters, 1986; Lee, 1993). The adaptive approach to environmental management also places a premium on continual evaluation of the results of research and monitoring, particularly that directed to measuring responses to management actions. For that reason, careful attention should be directed to assessing the effects of the management actions which are already taking place, in particular the increased flow and diversions associated with the C-111 canal.

4. Emphasizes Integration and Modeling

The Panel underscores the need, recognized in the Strategic Plan, for integration and synthesis as ongoing activities, not something to be reserved for some later phase. The Research Team approach included in the Strategic Plan is an essential ingredient. Based on the Science Conference presentations, in which investigators were charged with presenting the results of several allied investigations, it is clear that the team process is just beginning. We urge that this be given high priority during the first half of 1997. The ambitious modeling effort will be another essential mechanism for engaging the investigators in synthesis. It is important that the investigators contribute not only data required to satisfy model requirements, but also ideas about critical processes which constitute the framework for the model.

In addition, the full-time science program manager position is crucial, particularly for effective exchange of information as well as the difficult task of assuring that various model exercises are integrated effectively. The Panel strongly approves such an appointment and urges the PMC to take steps to make it a reality. The appointment of an experienced scientist with appropriate leadership skills for a term appointment (e.g. two years) through an IPA should be explored. It is not clear whether the science program manager should just serve on the model integration research team or serve as its chair. It will be difficult for this manager to oversee model integration without some authority. The authority and responsibility of the science program manager needs to be developed beyond the concept briefly stated in the Strategic Plan.

SPECIFIC COMMENTS ON PROGRAM ELEMENTS

Central Question #1

There are numerous and costly Program Elements identified and a mechanism for integration in terms of the Florida Bay Circulation Model. As discussed in detail in the above review of Science Conference presentations, a more detailed plan for their integration, including time lines for the provision of key information, should be developed.

Central Question #2

The statements of “what is known” regarding the distribution and supply of nutrients are not completely consistent with presentations made at the 1996 Science Conference, particularly concerning “richness” in nitrogen (1), evidence for the lack of N-limitation (3) and its relationship with bioassay results, higher nutrient concentrations in the “core” area (5), and the similarity of nutrient loadings from the Everglades to “natural background levels” (7). These statements should be carefully revised to be consistent with all the evidence and avoid bias toward the PMC “establishment view.”

There are eight Program Elements, each of which is complex. A mechanism for prioritizing these elements (and thus their funding) needs to be addressed. The nutrient mass balance is one excellent mechanism, and there is probably sufficient information for this to be done as soon as possible. The seagrass workshop should set a goal of organizing and evaluating seagrass data relevant to a nutrient mass balance. For example, there are several decent published data sets for the effect of various tropical seagrass species on nutrient pools in carbonate sediments that provide sufficient data for the model and a starting point for research if not.

Program Elements that measure internal nutrient fluxes and process rates are particularly important at this phase of the program if one is to relate nutrient budgets to plankton blooms and the carbon system in general. Although N transformations are mentioned in the introductory paragraph, the two elements listed (6 and 7) concern only P. Internal N cycling is potentially also important in the Western Bay and Gulf Transition Zone (at least based on bioassay results) and should be investigated. Also, there was concern over artifacts in the ongoing benthic P flux studies at the Annual Conference; these should be reviewed carefully before pursuing them further.

Central Question #3

Again, the “what is known” section should be carefully revised to eliminate any unjustified bias toward the salinity stress/seagrass die-off/sediment release of P/algal bloom hypothesis. It is stated in the introductory paragraph that the presumption of blooms being fueled by P release from sediments is “not clearly established,” so write the rest of the statements accordingly. The statements (2 and 3) indicating spreading and implying the need for “seeding” also do not seem justified based on existing results. Finally, the evidence of N-limitation from the bioassays seems deliberately understated (5).

Understanding the nutrient economy of blooms is particularly important to solving the bloom riddle. Answering the two “need to know” questions which relate to this (2 and 3) will not be sufficient. Simply identifying and quantifying sources of nutrients and defining physiological adaptations of dominant species will not provide the understanding needed. Blooms exist in a multi-species world in which recycling of nutrients is probably very important.

The heading “Program Elements” is missing on page 22. Following the above observation, Program Element 2 is unlikely, alone, to provide the needed understanding on bloom nutrition and regulation. The PMC should consider the recommendations of the Ad Hoc Committee on Nutrients (based on the July workshop) regarding more modern approaches to research on natural phytoplankton communities.

Central Question #4

The “overmaturation” hypothesis needs to be more explicitly defined in order to help prioritize future physiological ecology studies. Biomass levels before the die-off were certainly within the range—and perhaps within its low end—for seagrass beds in Florida. What is overmaturation and what are the hypothetical consequences that would initiate die-off?

Thalassia is notably slow to recover from disturbance (>6 y for a 1 m^2 patch surrounding by well-developed turtlegrass). This should be explicitly recognized by managers and a decision made as to whether the loss of fisheries support functions are sufficient enough to try implementing transplantation programs as part of the restoration plan. Public education about the other seagrass species might be important.

Seagrass physiological/ecological models need to be based on biomass, growth, and canopy cover rather than on metabolic rates of pieces of plants or leaves. Models derived from the latter are not population-based and have failed to accurately predict field responses to forcing functions.

Central Question #5

The focus on a few key economically-valuable species is important. However, understanding the role of the benthos in nutrient cycling and algal bloom dynamics is also critical. Having said that, the list of Program Elements seems quite long. Some seem to address second-order questions, relatively far removed from the essential questions regarding the dysfunction of Florida Bay and management strategies for restoration.

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